

Systems Thinking: the Explanation of Continuous Change

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V

DISCONTINUITY
AND LONG-TERM
CHANGE

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One of the apparent limitations of the systems approach, indeed of many analyses of change, is that it is altogether *gradualist* in nature. It leads one to see how, by a long series of steps, changes can be reinforced by a process of positive feedback, so that in the outcome marked and irreversible change ensues.

The archaeological record, on the other hand, often shows relatively sudden changes which cannot at first sight be explained in these gradualist terms. A decade ago, when diffusionist or indeed migrationist thinking was still widely prevalent (see Adams *et al.* 1978), the temptation to explain sudden change in essentially migrationist terms was still a strong one, even though a processual approach was more readily accepted for changes which took place in a more gradual way. Indeed the distinction between sudden and gradual was linked, in the minds of some, with that between historical and processual explanation. Historical explanations, it was felt, were appropriate to the understanding of events, while processual explanations, perhaps in systems terms, were conceivably acceptable for more gradual, long-term changes. This was to some extent the view of Sabloff and Willey (1967), which was called into question by Binford in his 'Some comments on historical versus processual archaeology' (Binford 1968).

The difficulty of relating sudden change to more gradual processes is one that underlies much historical discussion, and it has been treated with clarity by Braudel. 'Events are the ephemera of history'; (Braudel 1973, 900) they are to be contrasted with 'persistent structures' and 'the slow progress of evolution'.

It was the purpose of the two papers which follow to show that sudden change need be no less 'processual' than gradual variation through time. That is to say that sudden change, which would certainly be perceived by participants as a significant event or series of events, can be the direct and intelligible result of the operation of more gradual factors which we can describe in a perfectly straightforward way, whether or not in the language of systems thinking.

This I regard as a major methodological point and – speaking for myself – a lesson which once learnt in one context may equally be applicable in another.

The body of theory which for me solved this problem in an elegant and persuasive way was Catastrophe Theory, as developed by the French mathematician René Thom, whose book *Structural Stability and Morphogenesis* (Thom 1975) carries many overtones of interest for history (and archaeology) as well as biology. Christopher Zeeman has applied these principles in a number of interesting specific cases: his treatment of stock exchange collapse (Zeeman 1974) is one of the most suggestive to the archaeologist. The application of similar reasoning to the phenomenon which I have called systems collapse, and in particular to the sudden demise of various early state societies allows the discontinuous (the event) to be explained coherently in terms of the continuous (the process).

At this point a word of caution is in order. For, as many critics have pointed out (e.g. Zahler and Sussman 1977) Catastrophe Theory can readily be misunderstood, and be thought to be explaining rather more than is in fact the case. What it does do, very effectively, is show how the change in question may be expected in some cases to be sudden. In the cases I am dealing with it is the *suddenness* of the change which is being explained by these means. The question of why the change should occur at all (be it sudden or gradual) is an altogether different one, and one which it is up to the archaeologist to elucidate in the cases presented here. Catastrophe Theory is not some all-purpose explanatory device, able to bring instant enlightenment in all fields of endeavour. Indeed it is appropriate to note the words of the mathematician Stephen Smale in the context of his critical review (Smale 1978, 1365) of Zeeman's volume on the application of Catastrophe Theory (Zeeman 1977):

Good mathematical models don't start with the mathematics, but with a deep study of certain natural phenomena. Mathematical awareness or even sophistication is useful when working to model economic phenomena, for example, but a successful model depends much more on a penetrating study and understanding of the economics.

What applies to economics applies with equal force, of course, to archaeology. The quality of the application is dependent entirely upon the appropriateness of the model utilised. In several cases, however, the possibility of an analysis in terms of Catastrophe Theory has stimulated the more careful formulation of the underlying problem, with potentially useful consequences (e.g. Renfrew

and Poston 1979).

In the way in which I have sought to employ it (Renfrew 1978) it has two uses. The first, as I have described, is to help us to see why certain changes – which in themselves it is our job as archaeologists to explain – come about with discontinuous suddenness rather than more gradually. The second use, to which I will return below, is to help us understand the emergence of completely new forms: the phenomenon known to the biologist as morphogenesis.

In the papers which follow, once that simple but crucially important point has been accepted and assimilated, the detailed discussion in terms of the cusp catastrophe has not much further contribution to make (and I have shortened the mathematical formulation in chapter 13 for this reason). But I believe that the argument is nonetheless a very important one. For it solves very elegantly the problem of discontinuity, and in terms of the archaeological debates of a decade ago, it removes one of the last arguments for a migrationist approach. In saying this, of course, I am not trying to assert that migrations of people never occurred, nor that it is in any way inappropriate to seek archaeological evidence for them. The point, which is scarcely a new one now but was undoubtedly relevant in the '70s, is that evidence of discontinuity in the archaeological record is no longer in itself an argument for sudden causal factors such as perhaps the migration of groups of people.

These two papers, then, set out to explain the suddenness of two important kinds of changes which have, in the past, very widely been interpreted on the basis of their sudden nature, as the result of sudden causal factors of this kind. What comes out of both of them is something more than this however. The consideration of systems collapse led me to develop a general formulation of the phenomenon, set out at the beginning of the chapter, which turns out to be of relevance in quite a wide range of cases, and in a rather well-defined way. Rahtz (1982), for instance, has used this formulation in his consideration of Dark Age England, and the application seems to him a relevant one. In Chapter 13, the approach is presented in relation to the Mycenaean and Maya cases. The Maya collapse in particular has been the subject of a number of explicit formulations (e.g. Hosler *et al.*, 1977; Hamblin and Pilcher 1980; Doran 1981), which have much common ground between them. None, perhaps, elucidates so effectively the suddenness of the collapse.

The whole question of suddenness and discontinuity has recently been a matter of discussion and debate among evolutionary biologists considering the gradual or alternatively the sudden emerg-

ence of new species. The concept of 'punctuated equilibria' has enjoyed a considerable vogue (Eldredge and Gould 1972; Gould and Eldredge 1977; Gould 1980). The underlying idea is of course a very similar one. Indeed, when one is familiar with the basic ideas of Catastrophe Theory, the notion that species should emerge suddenly rather than gradually, if they are going to emerge at all, is altogether unsurprising, and has already been coherently expounded (Dodson 1976; Zeeman 1982). When these ideas have been fully worked out, we shall perhaps be able to lay to rest the misconception shared by Darwin (Maynard Smith 1982, 125) that 'gradual = natural; sudden = miraculous', and one of the obstacles to coherent thought in archaeology as in biology will have been removed.

The second issue which is raised here, at least by implication, is the phenomenon of long-term change. It is of course a fundamental point that sustained growth and significant change involve not simply alterations in scale but transformations involving fundamental restructuring (Renfrew 1979). This is precisely what the biologists term *morphogenesis*, the emergence of form, and the term is a useful one for the social scientist and the archaeologist also (Rosen 1979, 1982; Renfrew 1982). One important notion here is that of positive feedback, discussed in the last section (see Maruyama 1963) but the concept of growth, entailing significant changes in structure, implies something more.

I have the hunch that the various mathematical ideas in this general area, relating to the qualitative behaviour of dynamical systems, have much promise for those researchers, including archaeologists, who are concerned to study the emergence of structure. There are, of course, other approaches than Catastrophe Theory (e.g. Allen 1982), although this was my own personal introduction to the field. It is naturally important for the non-mathematician to avoid being seduced by the mystification which readily surrounds imperfectly understood mathematical formulations (Smale 1978, 1366). That, of course, is where one needs to draw upon the expertise of the relevant specialist (e.g. Pattee 1973; Poston 1979; Rosen 1982). Already, however, it is clear that informative new ways of looking at social change are possible (e.g. Waddington 1977; van der Leeuw 1981).

The cases chosen for discussion here appear to be among those where it is possible, and perhaps useful, to generalise, and to do so in a manner which applies to a whole range of contexts different in place and time. Despite the frequent claims among processual archaeologists that such generalisation is their goal, they have, with

a few honourable exceptions, conspicuously failed to employ wide ranging comparisons. Indeed one of the most conspicuous shortcomings of the New Archaeology in the United States is that much of it began in the American Southwest and never managed to move out of it.

Of course Julian Steward, one of the most influential of the precursors of the New Archaeology, attempted trial formulations of a very wide-ranging character (Steward 1949), and several other scholars have deliberately worked with more than one area and time period in mind (e.g. Flannery 1972; Athens 1977; Gall and Saxe 1977; Cherry 1978). But, as I suggested at the beginning of this volume, the problem of successful generalisation remains a pressing one.

But there inevitably comes a point, in any given case, when a certain level of detail is sought, and when the general framework can no longer serve as an adequate guide. General formulations always risk failing to satisfy in those instances when unique aspects of the individual case are under consideration: they only operate at a general level. Often, however, it is at that level that we can most effectively work. It is pertinent to quote once again the words of Braudel (1973, 1244):

In historical analysis, as I see it, rightly or wrongly, the long run always wins in the end. Annihilating innumerable events – all those which cannot be accommodated in the main ongoing current and which are therefore ruthlessly swept to one side – it indubitably limits both the freedom of the individual and even the role of chance.

The consideration of discontinuity and of morphogenesis thus leads on to wider issues of great interest. But neither of these papers sets out to explain a particular event, or even to show in full and convincing detail how a particular case falls within the scope of some more general regularity. To do that in a satisfying way it is necessary to work also at a more concrete level, and to consider how specific and contingent features of the society in question were able to determine or at least to condition its future behaviour. Broad generalisation alone is not enough. I am very much aware that a satisfying explanation of the particular case will not only show how it is a specific instance of processes more discernible, but at the same time show how local particularities helped to determine its own characteristic pattern of growth and development.

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SYSTEMS COLLAPSE AS SOCIAL TRANSFORMATION

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THE MYCENAEAN POLITY never really recovered from the onslaughts made on it at the end of the thirteenth century. The elaborate administration that had maintained its power disintegrated, its trade which was its life blood was disrupted and the fabric of its society decayed to an inglorious end. We are on the threshold of the Dark Ages.

Lord William Taylour (1964, 178)

Introduction

Many writers in different areas have described, quite independently, the archaeological evidence in their region which clearly documents the sudden collapse of an early state society. Suddenly, and without any very obvious cause, a brilliant and flourishing society with a highly structured, central administrative organisation disappears from the archaeological record. The immediate aftermath is always less clearly understood, because the range of archaeological evidence is much less adequate. Sometimes literacy is lost: always written records (if any) are notably fewer. The early state society fragments into a whole number of smaller units which (if they can be defined at all) are at a much lower level of sociopolitical integration. There is a decline in many activities, including craft-specialist production and trade, and often of population.

The overwhelming impression is one of discontinuity, and it is natural that in every case archaeologists have sought the cause of the collapse in some overwhelming cataclysm, either a natural disaster or a destruction through invasion. Yet, except in rare cases where a sudden natural cataclysm such as a volcanic eruption is evidently the cause, the precise explanation of the collapse remains elusive.

Further research generally shows that although the organisation-

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al structure did indeed disappear, there are elements of continuity with the succeeding period, the 'dark age.' Almost invariably the progress of research makes that Dark Age less dark, and reveals a pattern of less highly structured societies showing some of the organisational features recognised in the early developmental phases of the state society many centuries (or even millennia) earlier. Often the first, obvious explanation for the collapse, that it was brought about by the irruption of invaders or destroyers, proved difficult to substantiate. Frequently other monocausal explanations show themselves equally inadequate.

In each case the society has 'relaxed' or 'relapsed' organisationally with striking discontinuity, although continuity of certain other elements persists (usually, for example, there is no immediate language change). The collapse of central power is followed by competition among various small power groups inside the former territory and on its borders. The new central organisation which in many cases develops in the same area often after a few centuries traces its origins back to one of these small groups. Indeed the new administration may seek to legitimatise its authority either by claiming direct lineal descent from the previous state, or alternatively by claiming to have overthrown it by heroic force of arms, a claim often all too readily accepted by later historians.

This scenario has deliberately been expressed in very general terms, and I think it will be recognised by archaeologists in many parts of the world. It seems to represent a rather general pattern, a type of change widely distributed in space and time among early state societies. It is this kind of diachronic pattern which I have sought to characterise (Renfrew 1979, 16) as an allactic form.

Before giving specific examples, it may be worth setting down more precisely some of the very general characteristics that specific instances of this allactic form often display. It then becomes pertinent to seek an underlying explanation for these repeated patterns, and here catastrophe theory can help form our thinking. The following section owes much to a discussion by Adams (1973, 22) of the Classic Maya collapse, and rather more to descriptions of the Mycenaean Dark Ages (e.g., Snodgrass 1971, Desborough 1975), like that which is quoted at the beginning of this chapter.

General Features of System Collapse

Collapse

1. Collapse of central administrative organisation of the early state :
 - a) Disappearance or reduction in number of levels of central

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- place hierarchy
- b) Complete fragmentation or disappearance of military organisation into (at most) small, independent units
- c) Abandonment of palaces and central storage facilities
- d) Eclipse of temples as major religious centres (often with their survival, modified, as local shrines)
- e) Effective loss of literacy for secular and religious purposes
- f) Abandonment of public building works
- 2. Disappearance of the traditional elite class:
 - a) Cessation of rich, traditional burials (although different forms of rich burial frequently emerge after a couple of centuries)
 - b) Abandonment of rich residences, or their re-use in impoverished style by 'squatters'
 - c) Cessation in the use of costly assemblages of luxury goods, although individual items may survive
- 3. Collapse of centralised economy:
 - a) Cessation of large-scale redistribution or market exchange
 - b) Coinage (where applicable) no longer issued or exchanged commercially, although individual pieces survive as valuables
 - c) External trade very markedly reduced, and traditional trade routes disappear
 - d) Volume of internal exchange markedly reduced
 - e) Cessation of craft-specialist manufacture
 - f) Cessation of specialised or organised agricultural production, with agriculture instead on a local 'homestead' basis with diversified crop spectrum and mixed farming
- 4. Settlement shift and population decline:
 - a) Abandonment of many settlements
 - b) Shift to dispersed pattern of smaller settlements
 - c) Frequent subsequent choice of defensible locations – the 'flight to the hills'
 - d) Marked reduction in population density

Aftermath

- 5. Transition to lower (cf. 'earlier') level of sociopolitical integration:
 - a) Emergence of segmentary societies showing analogies with those seen centuries or millennia earlier in the 'formative' level in the same area (only later do these reach a chiefdom or 'florescent' level of development)
 - b) Fission of realm to smaller territories, whose boundaries may relate to those of earlier polities

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- c) Possible peripheral survival of some highly organised communities still retaining several organisational features of the collapsed state
- d) Survival of religious elements as 'folk' cults and beliefs
- e) Craft production at local level with 'peasant' imitations of former specialist products (e.g., in pottery)
- f) Local movements of small population groups resulting from the breakdown in order at the collapse of the central administration (either with or without some language change), leading to destruction of many settlements
- g) Rapid subsequent regeneration of chiefdom or even state society, partly influenced by the remains of its predecessor
- 6. Development of romantic Dark Age myth:
 - a) Attempt by new power groups to establish legitimacy in historical terms with the creation of genealogies either (i) seeking to find a link with the 'autochthonous' former state or (ii) relating the deeds by which the 'invaders' achieved power by force of arms
 - b) Tendency among early chroniclers to personalise historical explanation, so that change is assigned to individual deeds, battles, and invasions, and often to attribute the decline to hostile powers outside the state territories (cf. 5f)
 - c) Some confusion in legend and story between the Golden Age of the early vanished civilisation and the Heroic Age of its immediate aftermath
 - d) Paucity of archaeological evidence after collapse compared with that for preceding period (arising from loss of literacy and abandonment or diminution of urban centres)
 - e) Tendency among historians to accept as evidence traditional narratives first set down in writing some centuries after the collapse
 - f) Slow development of Dark Age archaeology, hampered both by the preceding item and by focus on the larger and more obvious central place sites of the vanished state

Diachronic Aspects

7. The collapse may take around 100 years for completion (although in the provinces of an empire, the withdrawal of central imperial authority can have more rapid effects).

8. Dislocations are evident in the earlier part of that period, the underlying factors finding expression in human conflicts – wars, destructions, and so on.

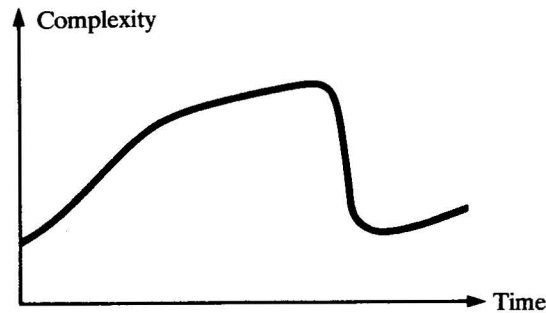


Figure 1. System collapse: the sudden decline observed in several early state societies.

9. Boundary maintenance may show signs of weakness during this time, so that outside pressures leave traces in the historical record.

10. The growth curve for many variables in the system (including population, exchange, agricultural activity) may take the truncated sigmoid form seen in figure 1.

11. Absence of single, obvious 'cause' for the collapse.

These criteria seem sufficient to document a social allactic form in much the same way as, for example, astronomers recognise that different stars in the sky are, on the basis of their short-term behaviour, to be classed as supernovas. Likewise, vulcanologists classify volcanic eruptions on the basis of behaviour through time as well as their geochemistry, into eruptive types, of which Plinian eruption is familiar to archaeologists for its destructive effects upon human settlement. It is claimed here that early state collapse ranks with supernova formation and Plinian eruption as an allactic form – all three classes of allactic form sharing a behaviour of sudden change after a much longer period of quiescence.

It is interesting to speculate whether early state collapse may in some cases be cyclic in nature – as Plinian eruption is – while supernova formation is not.

Space does not allow different specific cases to be presented in detail. I hope to present elsewhere a consideration of the end of Mycenaean civilisation in these terms. One feature that does emerge from such a comparison, however, is the remarkable extent to which not only the symptoms of the collapse are often comparable, but also the *explanations* which have been offered for them

by scholars working quite independently in different areas (compare Sabloff 1973, 36 with Rhys Carpenter 1966).

Among specific cases that I would claim as instances of the more general allactic form whose characteristics have just been outlined are the following:

The Mycenaean civilisation. A paradigm case for a 'Dark Age' in the Old World (see Desborough 1975, 663, Snodgrass 1971, Ålin 1962).

The Minoan palaces. Around 1450 BC, towards the end of the Late Minoan Ib period, nearly all major administrative sites in Crete, whether palaces or villas, were destroyed (Hood 1973, Marinatos 1939, Page 1970). Sometimes an explanation for this decline has been sought in the volcanic eruption of the nearby island of Santorini (cf. Ninkovich and Heezen 1965), but this simple explanation may not be sufficient. Invasion by mainland Mycenaeans is another recognised possibility, but there is at present little evidence to suggest whether this was immediately prior to or after the destruction of the Minoan palaces. Curiously the demise of Minoan civilisation at this time, some three centuries before the Mycenaean quietus, has not often been treated together with the latter as an instance of systems collapse.

The Indus Valley civilisation. The great cities of the Indus Valley civilisation, notably Mohenjo-daro and Harappa, flourishing round 2000 BC, were destroyed some time around 1800 BC (Piggott 1950, Wheeler 1968, Allchin and Allchin 1968). The explanations offered focus either on some specific and radical environmental change or on the supposed invasion of Aryans from the north and west.

The Hittites. The Hittite empire of central Anatolia ended around 1200 BC. The great Hittite capital of Bogazköy was destroyed, other important sites such as Alaca and Alishar were likewise destroyed by fire, and in the central area of the empire, literacy ended (Akurgal 1962, 75). This pattern is conventionally accounted for the activities of Phrygian barbarians who 'overthrew' the Hittite empire but whose military success diminished further south.

Egypt: First Intermediate period. At the end of the Sixth Dynasty of Egypt, 'the central power was too weak and divided to hold back the surging tide of anarchy, and the civilisation of the Old Kingdom was swept away with the political system which had created it' (Aldred 1961, 100). Literacy was, however, uninterrupted, and the continuity of Egyptian culture was not totally ruptured. This may therefore be a doubtful case of systems collapse, but the period is certainly seen as a Dark Age by Bell (1971).

The Classic Maya. The paradigm case for early state collapse in the

New World. The whole subject has been reviewed in *The Classic Maya Collapse*, edited by Culbert (1973).

Tiahuanaco. There is evidence that the state organisation centred on Tiahuanaco in the Titicaca area of southern Peru underwent a striking and perhaps sudden decline in the twelfth century AD. The Wari empire of the Southern Highlands collapsed at about the same time, and pan-Andean unity dissolved into a series of regional traditions (Lumbreras 1974, 159; cf. Sanders and Marino 1970, 80). This may provisionally be considered a possible case of early state collapse.

Other cases. Collapse has been claimed for China in the 'Warring States' period, and no doubt other cases can be documented. A rather different phenomenon, certainly related to system collapse as defined here, is the withdrawal of central, imperial power from a province of empire formerly held under strong military rule. Britain at the end of the fourth century AD offers a well-known example, and the 'Dark Ages' of Britain conform in most respects to the description given earlier, although it is difficult to regard the collapse in Britain as entirely endogenous.

The discussion here focuses on the collapse of early states, where the similar trajectories followed constitute the allactic form which we have sought to define. But it is relevant to note that relatively sudden collapse seems to be a feature of other societies with a degree of centralised organisation. One of the best documented and most interesting cases is the sudden decline of the Anasazi town sites in the southwestern United States in the thirteenth century AD (cf. Vivian 1970). Various cataclysmic explanations have been offered (Martin, Quimby and Collier 1947, 146), including 'a great epidemic of some virulent but unknown disease.' A multicausal explanation of the kind offered here for early state collapse may prove more satisfactory.

Stability and the Growth of Systems

Before turning, in the following section, to catastrophe theory, I would like to focus here on two very simple insights relating to complex societies. The first relates to hyperdevelopment, and the second to stability and growth.

Before the Crash: The Options Narrow

To adapt too well, too fully, and too effectively to present conditions may be to restrict the flexibility of response available to cope with a future change in those conditions. This is a truism of evo-

lutionary biology, where high specialisation can prove highly adaptive for a species in the short term but fatal in the long. Perhaps too it holds for many cases of system collapse.

In many early state societies there was a high degree of specialisation among craftsmen and even among agriculturalists, co-ordinated by a central bureaucracy. Efficiency of production *per capita* was greatly increased by this specialisation but the price was a very high measure of interdependence. A craftsman (e.g., a potter) working full time could produce far more of his product and of far better quality than could five farmers each devoting one-fifth of his time to making the same product. In favourable conditions, then, it is very sound strategy for a society to maximise specialisation through the agency of a central redistributive organisation. In this way it is possible, through economies of scale, to support a very much larger population than would be the case if each individual family or village had to be largely self-supporting, producing all the commodities which it used.

The danger may come, however, if the external circumstances become less advantageous, so that it becomes difficult to support the existing population. The option of becoming less specialised is not open to the society or to its decision-making agency at the centre. For although this would meet the change in external circumstances, it would mean a decrease in productive capacity, at least temporarily, and hence starvation for some of the community, which might in turn endanger the stability of the whole.

The only alternative is to increase productive efficiency by further increasing specialisation. To specialise in this way, instead of to diversify, seems a natural homeostatic adjustment. If, however, external circumstances worsen, the situation may cross the homeostatic limits of tolerance of the system which simply cannot manage any longer and breaks down. That is to say that even further specialisation and an increased work load cannot prevent a fall in production, with consequent starvation and perhaps unrest which will endanger the survival of the central bureaucracy.

Systems of this kind which, by virtue of their high specialisation, depend heavily on the central bureaucracy to distribute the necessities of life, are highly vulnerable. For if the central bureaucracy is disrupted and the distribution of products ceases, there is a sudden drop in efficiency and those specialists who are not actually producing food risk starvation. One imagines very much of this situation for the palace-centred polities of Mycenaean Greece, whose administrative archives have been preserved at Pylos and in part at

other centres. The collapse of a central polity there might well prove irreversible, and there are special factors, such as the very long time needed to cultivate young olive trees before achieving effective production should the olive groves be destroyed, which reinforce this effect.

This phenomenon is what Rappaport (1978) has termed 'over-segregation' or overcentralisation, and is related to Flannery's (1972) 'hyper-coherence' or 'hyperintegration'. The system has adapted to existing diversity in the environment by specialising and centralising: This makes it very effective for limited changes, but in the face of sustained change it may simply collapse.

Betancourt (1976) has written illuminatingly in similar terms about the Mycenaeans, and Willey and Shimkin (1973, 490) analyse the Maya collapse as follows:

The success of the system produced growths of population and of competing centres which led to increasing rigidity in the system as it was subjected to internal stresses and external pressures. The system failed through inadequate recognition of these stresses and pressures and through inappropriate responses to them. The economic and demographic bases of the society were weakened; the consequences were the collapse of the system, the decimation of the population, and a retrogression to a simpler level of sociopolitical integration.

It is worth noting that several 'crash' phenomena in human society are of this general kind, where the only available response to a severe deficiency of strategy is to work more intensively at the same strategy. A sure way for a gambler to avoid loss may be to keep betting on the same number, doubling the stake at each throw. But if he is unlucky assets will run out before his number comes up. Stock exchange crashes are sometimes caused by an analogous 'overheating' effect. The attraction to speculators of a rising index favours speculative buying, thus pushing share prices still higher. Profits can be realised only by selling: The price falls and the crash comes. The crisis of confidence which results in bankruptcy can arise when a financial organisation becomes 'overstretched' in a similar manner.

The Dangers of Zero Growth

For some human societies, stability (in the sense of peace and prosperity) is assured only by continued growth. Zero growth does not for them represent a stable state, and negative growth can accelerate to disintegration.

It is generally argued that stability and long-term survival in a system are assured through homeostasis. There is some resistance to any innovation, and such change as comes about is regarded as a response to outside stimuli, by way of a minimal adjustment to them. But when we are talking of culture change we are concerned with sustained growth, which somehow overcomes the negative feedbacks of the homeostatic controls. Sustained growth comes about through positive feedback effects, not only within individual subsystems but between subsystems – the multiplier effect (Renfrew 1972; chapters 9 and 10 above).

It is possible, therefore, to model growth by constructing a system with strong positive feedback loops which can outweigh in their effect the homeostatic, negative feedback loops (Cooke and Renfrew, chapter 11 above). Yet if there is an external factor tending to reduce growth or even induce negative growth, the rate of growth of the system may ultimately become zero. And a system with strong positive feedback loops and zero growth will usually be in an unstable or metastable situation, for a small negative growth will be reinforced during the growth phase and magnified, giving an increased rate of decline. A crash can easily be modelled in this way (see Hosler, Sabloff and Runge, 1977).

There are, moreover, indications that some subsystems of society can become adjusted to a steady positive rate of growth in such a way that this same rate can be peacefully sustained over a longer period, whereas a reduction to a smaller (but still positive) rate will have disruptive effects. In many modern Western economies, for instance, a positive rate of growth is considered the norm, and if wage rates do not increase, in real terms, by a positive amount each year, there is dissatisfaction.

If a society is to adjust to zero growth after a prolonged period of positive growth, it must disconnect the positive feedback loops which made that growth possible. Such an adjustment may not be easy, and if it is not brought about, the multiplier effect may produce collapse. Bryan Feuer (1974) has fruitfully applied this model to the collapse of Mycenaean civilisation.

The Cusp Catastrophe

A general description of the process of early state collapse can be given using the cusp catastrophe (Amson 1974, Poston 1979, Thom 1975, Zeeman 1977). Limitations of space prevent a full discussion of the model employed, which has been concisely set out elsewhere (Renfrew 1978), but the outline is given here to sustain the new

ideas in the two succeeding sections.

The sociopolitical system under consideration, the early state, can be described by a number of variables whose values represent the circumstances, the states, of its various subsystems. We shall choose a single variable, which could be one of these subsystem variables or some function of them, to represent in outline the general behaviour of the system as a whole. Its value will change suddenly, for instance, when the system collapses.

For our model of early centralised society, we shall define this behaviour variable, *degree of centrality* D , which is represented as a coordinate x in the behaviour space X . This is some measure of actual control of territory by a central authority through a pronounced hierarchical structure. High values will be reflected archaeologically by a hierarchy of central places, by insignia of kingship, by the maintenance of bureaucratic records, and by the other epiphenomena of state society. But degree of centrality refers as much to the software, the social reality, as to the hardware, the stock of palaces and temples. It can change rapidly, indeed in a time no longer than it takes to cut a few throats. Indeed it should be thought of as some measure of the information-carrying capacity and effectiveness of the administration.

We visualise also a control space C , or parameter space, as a horizontal plane of points c with coordinates a and b . The choice of control variables is crucial to the model, as is a decision as to the number of control variables necessary. At first, to present the simplest possible example, the case with two control variables is chosen. Later four control variables can be considered. The proposed control variables are I , accumulated investment in charismatic authority, and N , net rural marginality.

Charismatic authority refers to the structured organisation in society which results in adherence to the polity which the centre symbolises. It is not a measure of popularity or belief but of the energy assigned to cultural devices used to promote adherence to the central authority. The second control variable, net rural marginality, relates to the economic balance for the rural population. On the income side of the account are the fruits of their agricultural or craft endeavour. On the debit side are the material contributions, in goods or labour, required of them by the central state authority as the price of citizenship and to escape punishment.

The idea of marginality is designed to give simultaneous consideration to productivity on the one hand, and the level of taxation or levy on the other. A given level of taxation may be entirely accept-

able at one stage, but if productivity *per capita* decreases (perhaps through increase in population) the same burden is heavier to bear and marginality is high.

The notion of a model, of any explanation, implies that there is a relationship between the state and control variables, although we do not always need to know precisely what it is. We suppose that the evolution (the dynamics) of the system is governed by a family of functions f_c , which we may think of as generalised potential functions. The stable states of the system under consideration are represented by maxima or minima of this function. In this case we may think of f_c as representing a measure of the viability or stability of the culture system. Another way of looking at this is to think of f_c as representing the 'attractiveness' of the system for the given value of x . The main hypothesis required for a catastrophe theory treatment is that the system in general acts so as locally to maximise f_c (when the function represents viability or attractiveness or benefit, or alternatively to minimize f_c when this is a potential function). The other important hypothesis is that of structural stability (genericity), discussed in detail by Thom (1975, ch. 3).

Thom's theorem, crudely paraphrased and assuming structural stability, states that if the number of control variables is no more than five any singularity (or specially twisted region of the map which underlies the discontinuities in observed behaviour) is equivalent to one of a finite number of types called elementary catastrophes (Thom 1975, 9; Poston 1979). In particular when there are only two control variables the only singularities of M , the graph of maxima and minima, are fold curves and cusp points.

The cusp catastrophe has the form seen in figure 2. A discussion of its properties is given by Zeeman (1977) and Amson (1974), and is not repeated here (see also Renfrew 1978).

We can now use the properties of the cusp surface M , and in particular those of discontinuity and divergence, to help us grasp the anatomy of system collapse. For instance, if we start with high values of a and b (in control space C), the corresponding point in state space X is on the upper sheet of the cusp surface M . x has a high value. But if the value of a steadily diminishes, while b holds steady with a high value, the movement of the control point c in C brings the point (c, x) along this upper surface toward the edge of the fold. When c enters the area of C enclosed by the bifurcation curve B , there are two values of x for each pair of values (a, b) corresponding, respectively, to the upper and lower sheets of M . If the system *locally* maximises f_c , it will stay as long as possible

without sudden change (following the delay rule), that is, until c reaches the other side of the region of bimodal behaviour, enclosed by the bifurcation set B . At this point there is suddenly only a single maximum of f_c , on the lower sheet of M , and x will undergo a sudden change of value. As a continues to decrease (if it does), change in x will now be smooth and steady again. It is this sudden change in x , corresponding to a discontinuous crash in the system, which represents for us the system collapse.

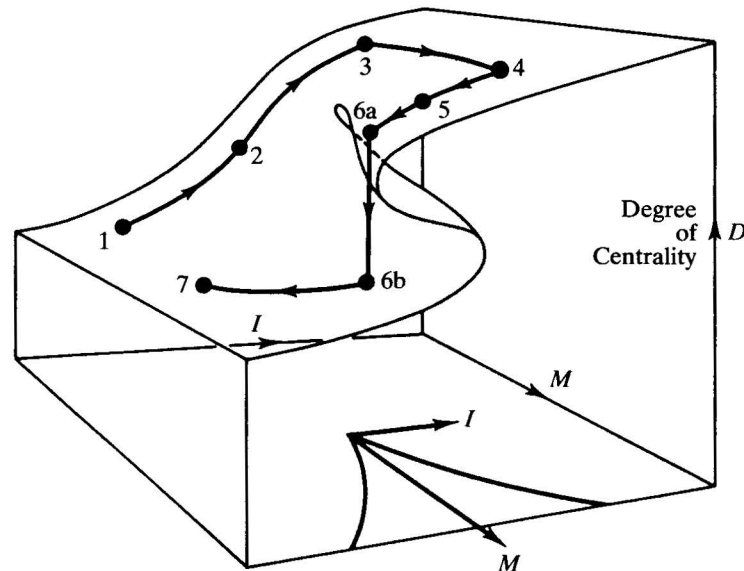


Figure 2. System collapse modelled by the cusp catastrophe.

We therefore postulate a function $f_{I,M}(D)$ that expresses in some appropriate form the stability and viability of the system, reflected in the well-being of the rural population. The rural population, indeed the system at large, acts in such a way as locally to maximise the viability f , taking into account the various constraints implied by I and M . D , the degree of centralisation, is here seen as reflecting the success or failure of the central authority in commanding or attracting the adherence of the rural population to the central system and hence ensuring its viability and survival.

Let us now follow a typical systems collapse time trajectory, as it might be for the Maya or Mycenaean civilisation. The story starts at point one representing t_1 . Marginality is low, and so is investment in

charismatic authority. The degree of centrality is low. This is a prosperous non-centred society, which may well be egalitarian. I increases, through points t_2 and t_3 , so that D increases: the state develops. But marginality is now increasing: it is no longer easy for the rural population to increase the *per capita* yield further in order to make the required contributions to the central administration. As population increases, or fertility decreases, or the tax burden is augmented, marginality now increases, with increase in I also to point 4.

But now the system is under stress, with high M , and I decreases slightly to point 5. There is now also a low value of D (on the lower sheet with the same values of I and M) for which efficiency is also a maximum. But the delay rule (representing the inertia of the system through its complex feedbacks) means that not until t_6 , when the local maximum vanishes altogether, does the value of D change suddenly (point 6b on figure 2). This very rapid change, the collapse of central government, will bring in its wake many other changes. In particular, the central personnel, no longer exercising control or imbued with the charisma that accompanies it, can no longer command I , the investment in charismatic authority. The instantaneous collapse of D (the rupture of centralised control) is followed by the rapid but slower diminution of I to point 7. The administrative population, with its specialist officials and craftsmen, either die or emigrate (or return to rural cultivation), and marginality is reduced (point 1).

This formulation, it should be noted, can take account of sudden changes in the external circumstances, caused for instance by a natural cataclysm, which can of course result in sudden changes in the control variables. These in turn may result in the catastrophe collapse of the system.

Acephalous and Centred Societies: Anastrophe

The cusp catastrophe model described in the preceding section was set up in order to seek some general explanatory formula for the very widespread phenomenon of system collapse. Like all models, however, it brings with it certain further properties and implications which were not envisaged in the initial formulation (Braithwaite 1953). These are themselves very interesting, and underline the fruitfulness of the approach.

Divergence

An important property of the cusp and higher order elementary

catastrophes is bifurcation. If two systems start off at L with identical initial conditions (with identical values for the control variables and for the state variable), they can end up with identical values for the control variables yet in very different final positions M_1 and M_2 (with different values for the state variable D). The final value of D depends not only on the values of the control variables a and b at that point, but on the *past history* of the system, that is, on the trajectory between L and M . This is an important property of culture systems.

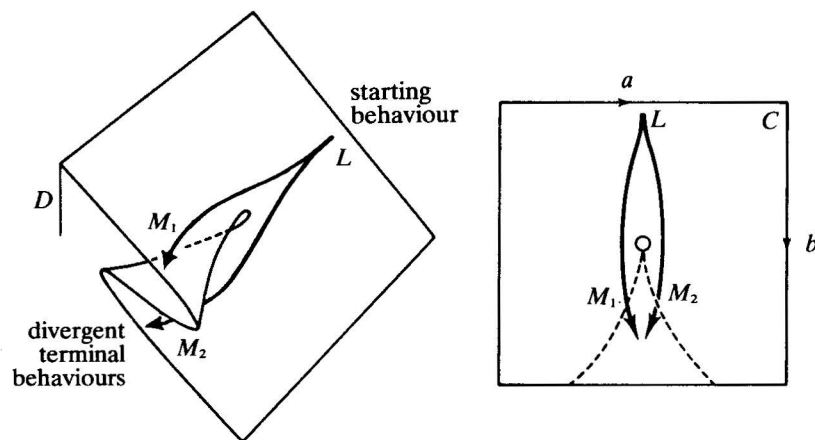


Figure 3. Divergence: two societies with analogous social organisations that start off at the same point (L) can finish with centralised authority (M_1) and acephalous structure (M_2) respectively, in the same environmental conditions.

This property is illustrated in figure 3. Two systems start off at point L . The first undergoes a slight increase in a (the normal factor) before being subject to substantial increase in b (the splitting factor); the second undergoes slight decrease in a before b increases. After the increase in b the value of a returns for each to the same initial figure. Yet one is now on the upper surface of the cusp surface, with high D , and the other on the lower, with low D . Of course if a were to decrease markedly, the first would undergo catastrophic decrease in D and both systems would again be in the same state. But there is no reason to expect this to occur. M_1 and M_2 are both stable states of the system or systems.

If now we consider a whole series of systems, starting off at or near L , with comparable initial conditions, as their subsequent

varied histories, we can predict that some will end up on the upper sheet and some on the lower sheet. At a given time, if b should be low they may show a fairly continuous distribution in terms of D (figure 4, upper). But if b should be high, the distribution will be a bimodal one, with many on the upper sheet (high D) and many on the lower sheet (low D) and very few with intermediate values of D (figure 4, lower).

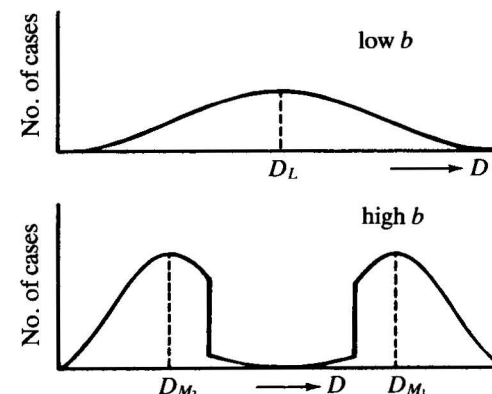


Figure 4. Frequency distribution of social forms (variable D , degree of centrality) when splitting factor b is low (*above*) and high (*below*) as predicted by the cusp catastrophe (see figure 3).

Now returning to the variables used in the preceding section, we can imagine a number of separate polities in a given region in similar environmental conditions. Initially the population density is low and other factors may work to keep marginality low. Some of these polities will invest in charismatic authority to some extent, others much less so. As population increases, and perhaps other factors operate to increase marginality, a situation will develop in which some societies will show a pronounced degree of centralisation, and others very little. If marginality is high, there will be few intermediate forms, although with low marginality the spectrum of centrality will be a continuous one.

It is interesting that this effect is precisely what some observers have recognised for traditional African societies. To quote Fortes and Evans-Prichard (1940, 5):

It will be noted that the political systems described in this book fall into two main categories. One group, which we refer to as Group A, consists of those societies which have centralised

authority, administrative machinery and judicial institutions – in short a government – and in which cleavages of wealth, privilege, and status correspond to the distribution of power and authority. This group comprises the Zulu, and Ngwato, the Bemba, the Banyankole, and the Kede. The other group, which we refer to as Group B, consists of those societies which lack centralised authority, administrative machinery, and constituted judicial institutions – in short which lack government – and in which there are no sharp divisions of rank, status or wealth. This group comprises the Logoli, the Tallensi, and the Nuer. Those who consider that a state should be defined by the presence of governmental institutions will regard the first groups as primitive states and the second group as stateless societies.

Some writers have sought to correlate the distinction with population density, and the foregoing analysis would tend to support the correlation, although it should be noted that population density is only one component of marginality, since environmental and social factors are also relevant. It has been argued recently that the distinction between group A and group B, between centred and acephalous, is very much an artefact of the observer, and that in reality the distribution is very much a continuous one. Inadequacies of observation or categorisation by the anthropologist are not, however, to be ascribed to the model itself: it simply predicts that, given the underlying assumptions and with a fairly high marginality, there will be a bimodal distribution corresponding to societies of group A and group B.

One of the features of African political organisation, however, which has particularly excited comment (e.g., Richards 1960) is that both centred and acephalous societies appear to exist in the same ecological region, often in close proximity, without apparent good reason to explain their coexistence or determine which form will be stable in a particular case. But this is exactly what our model predicts: that there should be stable states at M_1 and M_2 , with a high and a low value of D , respectively, corresponding to centred and acephalous polities (high and low D) in precisely the same environmental conditions and indeed with certain similarities in their internal functioning (represented by the same values of a and b – in terms of our model of I and M).

Clearly this observation merits much closer study, but it is exciting that the model appropriate for the analysis of system collapse should make predictions which go some way toward clarifying what

has hitherto seemed a paradox of political organisation.

State Formation: Anastrophe

After the collapse of an early state, we have predicted that feedback among the variables, and in particular from X to C , will reduce the marginality fairly quickly. Subsequent further investment in charismatic authority may lead to increase in degree of centrality. Increasing marginality and further changes could then ultimately lead to a further collapse, so that the behaviour might be cyclical (figure 5).

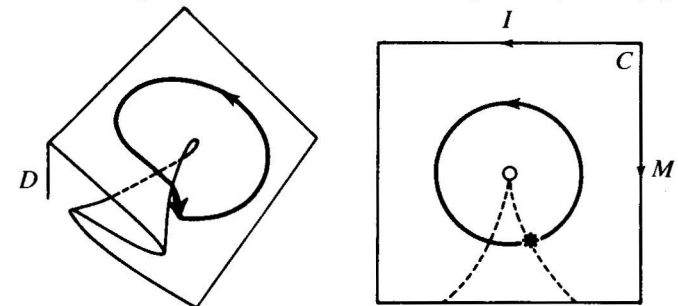


Figure 5. Cyclical state formation (gradual) and collapse are possible (left) as the control variables change (right). Catastrophe.

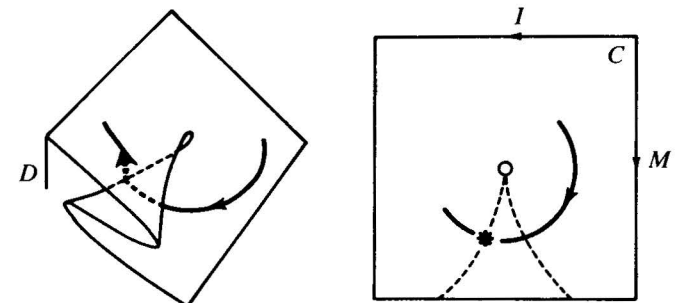


Figure 6. Anastrophe: if the control variables follow a path close to the reverse of that seen in figure 5 (right), sudden state formation can occur.

Yet there is nothing in the model to suggest that the feedback on the lower sheet necessarily always works to reduce marginality. Instead it is tempting to consider the circumstances in which a system on the lower surface, with low D , might undergo a sudden 'upward collapse' onto the upper surface, rapidly becoming a highly centred polity with high D . Within the context of the present discussion I propose to designate this phenomenon of 'upward

collapse' by the term *anastrophe* (figure 6). It is the counterpart, therefore, of the catastrophe of system collapse. From the mathematical standpoint, of course, sudden increase of D , like sudden decrease, is simply a discontinuous change of the state variable: Both are catastrophes (in the sense of Thom) with only the relatively trivial matter of a change of sign to distinguish between them. While recognising this, however, the distinction in the applied case does not appear trivial at all. So *anastrophe* will here refer to the discontinuous increase in the state variable D (which represents degree of centrality), and catastrophe to discontinuous decrease.

Continuous decrease of the normal variable a (in this case investment in charismatic authority), when the splitting variable b (in this case marginality) is held at a constant high value, produces a catastrophic decrease in D (degree of centrality). As we have seen, the system acts so as locally to maximize f_c with the operation of the delay rule, and the switch to the lower sheet is deferred until the last possible moment. The model predicts that for an acephalous society, when marginality is high, steady increase in investment in charismatic authority will produce an *anastrophe*, a discontinuous rise in D . The model is here predicting for us another allactic form, the rapid formation of this state. If we define D by the size of territory or population, the *anastrophe* will entail the fusion of a number of acephalous polities to yield a single centred society (state formation by amalgamation). Alternatively, if D is defined in terms of levels of hierarchical organisation without reference to scale, the *anastrophe* entails the sudden emergence of new structures of authority and administration by the insertion of a new hierarchical level, without any necessary change of scale (state formation by intensification). In practice sudden state formation will usually involve both these processes.

It is important to recognise that the model in itself, as formulated, tells us nothing of the nature of state organisation, and a fuller analysis would undoubtedly require a deeper insight into the hierarchical structure and communication network implied by high centrality. Nor does it tell us that state formation implies any discontinuity. When marginality is low, investment in charismatic authority and degree of centrality can increase smoothly together, just as has been envisaged in figure 5. What the model does do is to suggest that in certain conditions the state formation will be sudden, and to offer some suggestion as to what those conditions may be.

I suggest that the formation of the Zulu state may have been of this kind (see Gluckman 1960), and likewise the emergence of a

centralised Saxon kingdom with a state organisation in Britain in the ninth century AD.

The model itself does not indicate whether the *anastrophe* comes about as the result of war or by peaceful means. When an acephalous society is threatened by attack from outside, one response may well be to increase investment in charismatic authority, in the form of war leadership. But the change can also be a peaceful one: the formation of the Iroquois confederacy may be a change with elements of both.

The model here harmonises with, and I think helps to sharpen, the insights of Robert Netting writing of political adaptation in Africa (1972, 332 ff):

Let me suggest that political development in many cases takes place internally and voluntarily rather than by imposition or wholesale borrowing from neighbouring groups, and that the main lines of development and channels for change are pre-figured in existing institutions and patterns of behaviour.

In his discussion (1972, 233) he stresses the role of charismatic leadership in the genesis of state organisation:

I would claim that on the road to statehood, society must first seek the spiritual kingdom, the essentially religious modes of focusing power are often primary in overcoming the critical structural weakness of the state. . . . The overwhelming need is not to expand existing political mechanisms (they are in certain respects radically inelastic) but literally to transcend them.

The model propounded here suggests that increasing marginality, whether arising from increased population, circumscription or whatever, may be one of the preconditions for the sudden *anastrophic* formation of a state society. Intriguingly it is likewise a necessary condition for the catastrophic collapse of the highly centred political system. I find it illuminating that a model conceived to describe the latter process should also prove relevant to the former.

Transformations

What started as an analysis of systems collapse has taken us far further, toward an analysis, or at least a description, of the transformations by which polities change their nature. At the outset the notion of allactic form was put forward, of which systems collapse is one of the most clearly recognisable.

Yet one of the first lessons which the discussion underlines is that the sudden collapse of an early state society is simply one of a

number of possibly rapid changes of state of relatively simple agrarian societies. The most obviously discontinuous, or at least very rapid, changes in the archaeological record are collapses, catastrophes to use Thom's term. But the discussion reminds us that sudden formations, sudden increases in organisational complexity and centrality, here termed anastrophes, can also occur.

There is little doubt, also, that the analysis holds several more insights which I have not spelt out, or which I have not seen. For instance, it would seem to be true that the well-known cases of systems collapse entail a catastrophic switch from early state society to segmentary society without stopping at the intermediate level of centrality, the chiefdom, on the way. Why is this? Is it that the level of marginality has to be so high before collapse ensues that it has already exceeded the limits of tolerance of a chiefdom society?

The property of divergence allows us to see how it is that discrete social forms may be observed, without intervening variants, rather than a complete spectrum of societies. This is indeed one of the most interesting aspects of catastrophe theory, that it generates thresholds and hence different forms. Further applications are likely to cast some light upon similar sociopolitical dichotomies, among which the Highland Burmese distinction between *gumsa* (ruled by chiefs) and *gumlao* (repudiating hereditary class difference) is particularly well known (Leach 1964, chapter vi).

In this chapter I have tried to bring out the features which arise from the mathematics of catastrophe theory and those which arise from my own specific formulation. Undoubtedly the problems raised here could be formulated differently, although the use of a different vocabulary sometimes masks the reality that same distinctions are in fact being drawn. This is to some extent true, I feel, of Friedman's recent repudiation (Friedman 1974) of a systems terminology in favour of a neo-Marxian one. But without arguing that issue it is pertinent to remark that the notion of 'trajectory' is very much at home within the context used here, and that transformations between different system states or social formations in the sense of radical, possibly discontinuous changes are not only permitted but required by catastrophe theory. Indeed the terms transformation and catastrophe (or anastrophe) are in most cases interchangeable. It is not of course surprising that the study of structural stability and morphogenesis should illuminate 'structuralist' argumentation, but the underlying explanation or description of the transformations observed rests, in the case of catastrophe theory, on a much surer basis than an appeal to the altogether nebulous

concept of 'contradictions' (Friedman 1974, 465). The approach outlined here could, I feel, be translated into Marxist-structuralist thought (and language) to the benefit of the latter.

It must be admitted that many of the observations here do not derive directly from catastrophe theory: I do not claim to have 'proved' anything in the mathematical sense. Yet the theory has worked as a valuable heuristic tool. For archaeologists badly need a framework of thought that will allow changes to be studied and compared. The classification of elementary catastrophes encourages the hope that allactic forms may indeed be recognised so that the analysis of cross-cultural regularities can be set on a more sound and formal basis, without encountering the objections which many anthropologists seem to hold for ethnographic analogies. Naturally each culture at a particular time is unique, and the sequence of events will from one perspective be unique also. A model of this kind can describe only those features with which its limited level of complexity allows it to deal. My argument here is that there are certain underlying regularities which it is useful to discern and to analyse. Such a procedure can in itself allow us to define more closely the special or unique features of the individual process, but it will never predict the infinite complexity and variety of each individual case. In the words of René Thom (1975, 320):

It is tempting to see the history of nations as a sequence of catastrophes between the metabolic forms; what better example is there of a generalised catastrophe than the disintegration of a great empire like Alexander's! But in a subject like mankind itself, one can see only the surface of things. Heraclitus said, 'You could not discover the limits of the soul, even if you travelled every road to do so: such is the depth of its form'. [1979]

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